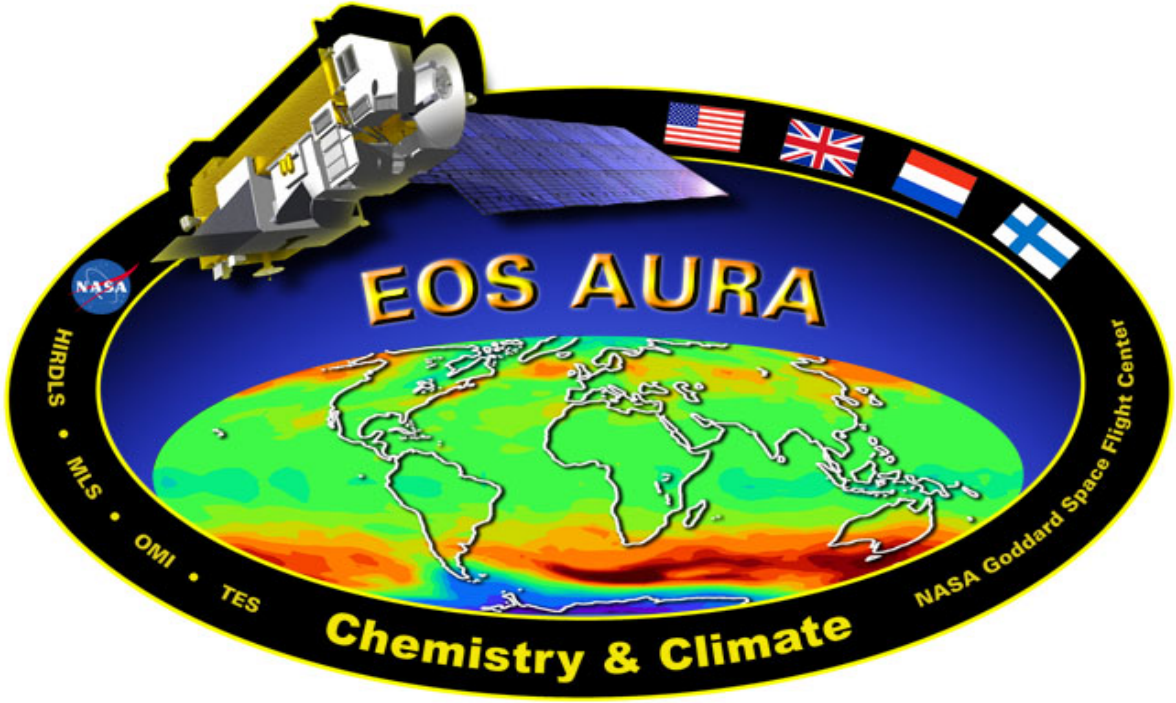
The Aura Mission

Mark Schoeberl

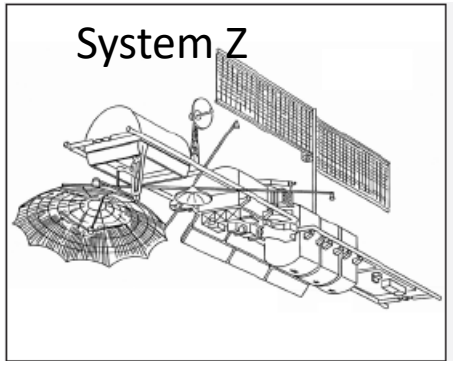
STC



Missing from the group shot: Gil Leppelmeier (FMI), John Barnett (Oxford)

Where did Aura come from?

Aura, part of Mission to Planet Earth, began with System Z….



- Shuttle launched System Z effort begins at NASA HQ – prototype for major earth observing initiative – mostly observing the water cycle. This effort tries to consolidates the independent Landsat, UARS and Topex missions. Early version has 19 instruments. Dependent on polar shuttle launches from Vandenberg. Polar shuttle launch facility later closed before construction finished..
- The Sally Ride report (1990) recommends 'Mission to Planet Earth' in the report *Leadership and America's Future in Space*. This concept is endorsed by additional National Academy documents and external reviews.
- MTPE Announcement of Opportunity selected 30 instruments and 29 interdisciplinary investigations. Among those instruments selected are MLS, SAPPHIRE, HIRRLS, DLS, TES.
- No 'TOMS' like instrument is selected, in fact, no PI Goddard instrument is selected. (MODIS is a facility instrument.) Goddard is embarrassed by this. Lots of finger pointing.
- MTPE is given a new start in 1990 with the Earth Observing System (EOS). Runout budget through 1990 is $17B.
- Proposed implementation is two 'Battlestar Galactica' (see figure) sized platforms EOS-A and EOS-B. General feeling is that if you aren't on EOS-A you won't fly. EOS-A has 17 instruments.

Implementation of EOS

- 1991 UARS is deployed from the shuttle
  - UARS Vax based data system is viewed as a prototype for EOS data system.
  - All of the UARS data ever taken is about the size of one MODIS granule, no one seems to realize this except Milt Halem who announces we will need a football stadium of 6250 bpi tapes to hold the EOS data. People are frightened.
- Congress cuts the MTPE budget to $11B in 1992 (calling it 'rebaselining')
- EOS investigators in 1992 begin down-selection process (the Payload Panel)
  - All of the ionospheric instruments are dumped
  - HIRIS – an $800M hyperspectral instrument favored by Jeff Dozier – the first EOS PS- is dumped
  - SAPPHIRE (Langley) vs MLS (JPL) shootout – MLS wins because of the MLS success on UARS and because SAPPHIRE uses a cryogen. SAPPHIRE focus on OH, MLS does both OH and ClO.
- Dan Goldin decides to 'rescope' MTPE by cutting an additional 30% bringing the program to $8B
- Congress (1994) makes additional 'reshaping' cuts to bring the program to $7.25B

The Rebaselined, Rescoped, Reshaped System

- Multiple platforms and stretched implementation
  - Three large platforms: AM, PM & CHEM; small platforms: ACRIMsat, 2 SAGE III's, SORCE
  - Spacecraft lifetime extended from 5 to 6 years (on paper).
  - Foreign instruments fill some of the measurement gaps – Canadian MOPITT is chosen over Langley MAPS; DLS (UK) is combined with HIRRLS (NCAR) to form HIRDLS (1992). UK makes substantial monetary contribution and builds HIRDLS calibration chamber. Japanese to provide a 'TOMS'.
  - The CHEM team decides to go last in the sequence of large platforms because UARS is already flying
  - CHEM planned for launch in 1998 (ha ha)
- CHEM Team gets organized and payload proposed (Jim Gleason, first PS)
  - Japanese drop out …
  - Dutch management is interested in developing a 'TOMS' to compete for the ozone instrument on METOP. But, GOME (DLR) is selected for METOP.
  - PK Bhartia and Ernie Hilsenrath persuade the Dutch/Finish consortium to provide their instrument to NASA. Ghassem Asrar (HQ) closes the deal. NASA provides the interface module for OMI.
  - The Dutch select Pieternel Levelt as the PI. Pieternel is the youngest PI of the team and can out run all of us – *easily*.

The EOS story continues…

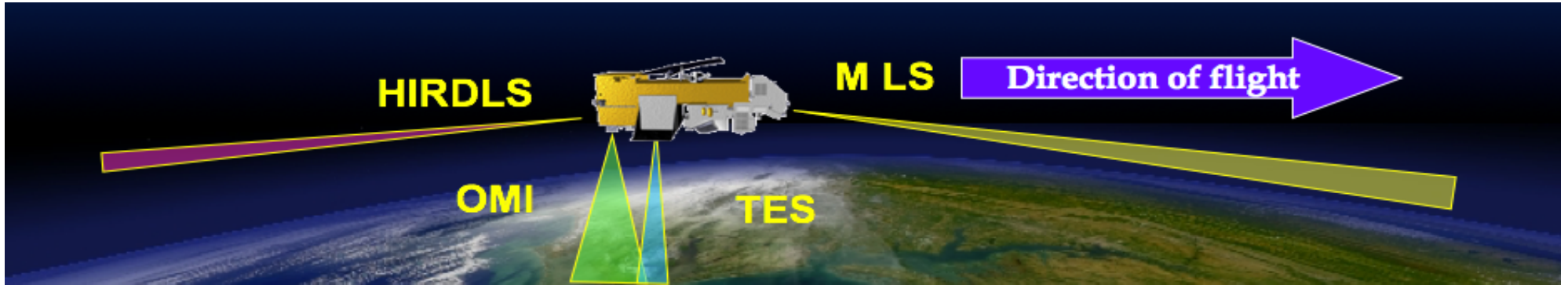
- Complaints about no new NASA opportunities for instruments or missions is heard by Congress.
  - NASA responds creating Earth Probe (later ESSP) program (e.g. Earth Probe TOMS)
  - More aircraft missions and funded .. including polar missions
- Data system design (DAACs – Distributed Active Archive Centers)
  - TRMM DAAC misses development deadlines (1997). EOS Team is concerned that NASA doesn't know what it is doing with data systems.
  - Distributed system proposed by community in response to worries that the Goddard monolithic approach won't work. The result: 12 Data Centers, 9 SIPS and a lot of confusion and complaining.
  - HDF chosen as format for data – meeting most of the user requirements
    - HDF had the additional *benefit* of making the data nearly unusable inside and outside of NASA. But it seems modern…
  - Data from all the Aura instruments to be hosted at the Goddard DAAC except for TES which goes to the 'Tropospheric Chemistry DAAC' at Langley along with MOPITT data.
- Three main platforms
  - NGST (formerly TRW) will build the PM bus and throw in an extra bus for 'free' – this is the Chem bus
  - AM changed to Terra – launched in late 1999 just before Y2K threatens civilization.
  - PM changed to Aqua – launched in 2002

CHEM -> Aura

- CHEM Payload finalized, UARS-like follow on instruments (MLS, HIRDLS) and tropospheric chemistry instrument (TES) with OMI linking the stratosphere and troposphere.
- Unlike **Terra** or **Aqua**, all **CHEM** instruments are synergistic.
- Arlene Peterson (the first Project Manager) is replaced by Peg Luce (now at NASA HQ)
- CHEM spacecraft design finalized 1996-1997 – MLS is the hood ornament
- Spacecraft PDR complete, Nov. 1999; CDR 2000
- Renaming contest: CHEM wins, but Ghassem Asrar says no. Aura is second place (suggested by J. Gille) and the team loved it.

  Some non winners….

  MLS, OMI, TES, HIRDLS Research in the Atmosphere (MOTHRA), BOZOS – Busy OZOne Scientists
- Working groups established (Algorithm, Data systems, E&PO ….)
- Aura Validation Data Center (suggested by E. Hilsenrath) is developed when it is realized that much of the Aura validation data will come from foreign sources such as ENVISAT and sondes and will be difficult to get from the DAAC.



Greek Statue of Aura
Nymph of cooling breezes
5th century BC

Photo by J. Gille

Some ancient texts say that the fluttering garment is made Kapton.

Instrument and Platform Headaches (just a few of many)

- Problems with Aqua Bus– NGST borrows parts from the Aura bus then HQ ‘borrows’ money from the Aura budget. We cynically suggest our name be changed to the the NASA ATM.
- Phil Sablehaus becomes PM, halts Lockheed work on HIRDLS in budget dispute.
  - Some say that this stop-work led to the Kapton problem after launch.
- Cost overruns for TES – Joe McNeal’s response ‘Leave JPL alone’ ; not so helpful
- Rick Pickering becomes PM after Aqua launch – the usual headaches continue
  - Star tracker sun shade has scratches, sunlight on the scratches look like stars
  - Rad tolerance of OMI CCD becomes an issue, 8 kg of aluminum shielding added.
  - HIRDLS has cooler issues – vibration balancer breaks. Fly as is…
  - MLS parts issues (HBTs*), and methanol laser (for OH) lifetime problems.
  - TES parts issues (Vishay Resistors); TES has alignment problems that show up after each bakeout, later we find that the translator bearings were overfilled with lubricant.

*Heterojunction Bipolar Transistor

Getting Ready for Launch – Instrument delivery

- Delivery of instruments to spacecraft is held up by TES alignment problems
  - OMI has to deliver first but they haven't completed ground calibration (lots of complaining in multiple languages about this)
- *Aura Project Manager remembers that they forgot to ask the Project Science Office for mission success criteria*
- Program Science (HQ) and Project Science put together a validation plan
  - Project Science Office fears that the aircraft folk will use up the Aura validation money while providing no useful (to Aura) data. This happened with SAGE III validation mission (SOLVE) which took place before SAGE III had even launched.
  - Mitigation – Project Science Team must be included in aircraft missions (PreAVE, PAVE, TC4..)

Measurements and Mission Success (Early Science Traceability Matrix)

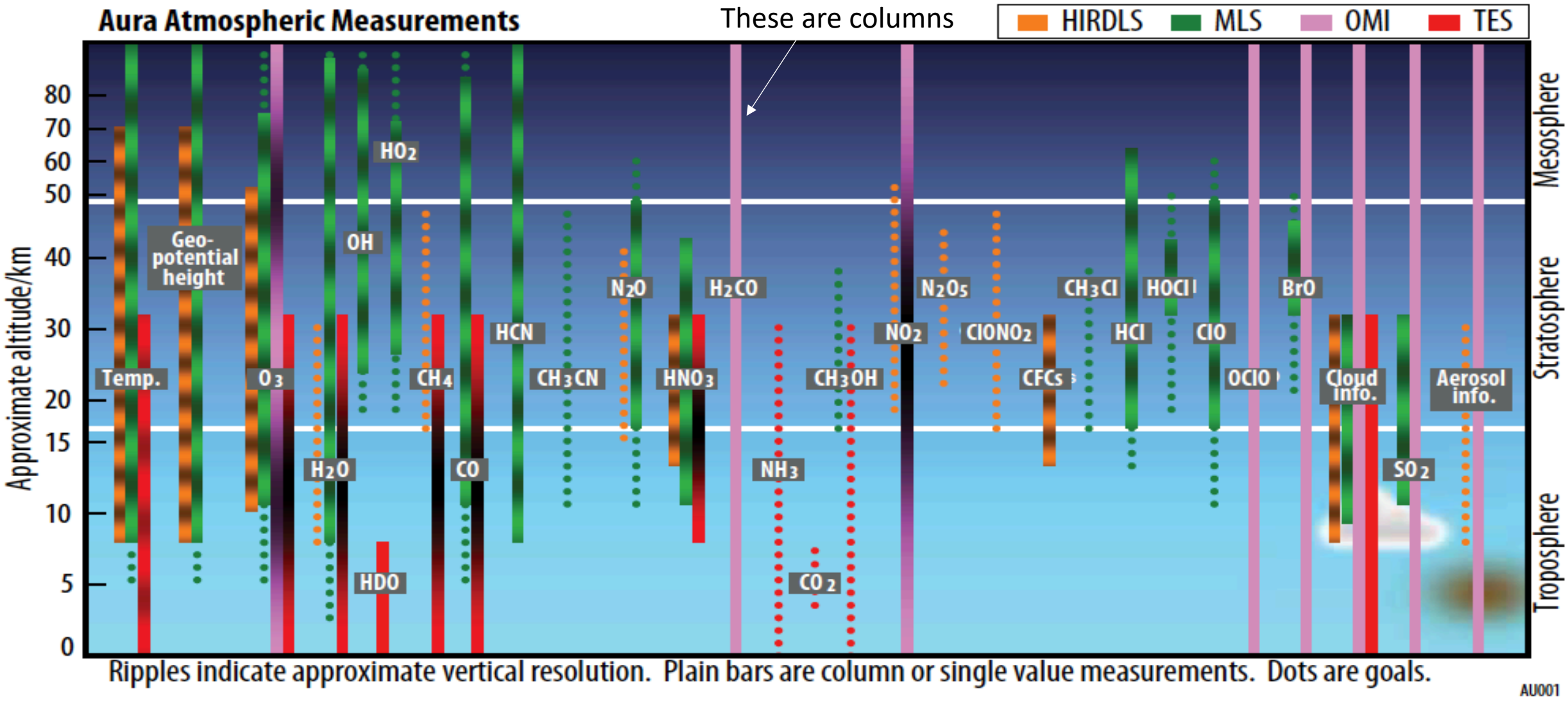
M. S. Goal	Approach	HIRDLS	MLS	TES	OMI
1. Quantifying the change in stratospheric ozone and extending the measurements of global column ozone for use in trend detection.	Ozone Trends *- need 3 years of column data*	Ozone profiles, 5% accuracy	Ozone profiles, 5% accuracy	Ozone profiles, 5% accuracy	Total ozone column – 3 yr life req. – 1.5% requirement, ozone profile 10%
	Ozone Chemistry Accuracy req. varies with species – *need 2 years of data*	NO_2, N_2O, $ClONO_2$ HNO_3, N_2O_5 CH_4, H_2O, F11, F12 Aerosol/PSC Composition	ClO, BrO, OH*, HO_2 HNO_3, HCl N_2O, H_2O, CO, HCN, HOCl, SO_2	NO_2 HNO_3 CH_4, CO, H_2O	OClO
2. Determining the linkage between climate change and changes in atmospheric constituents.	Upper tropospheric/ lower stratospheric O_3 and H_2O – *need 2 years of data*	Upper trop. O_3, H_2O, 5% accuracy	Upper trop. O_3, H_2O -5-10% accuracy (MLS Primary)	Upper trop. O_3, , H_2O 5-10% accuracy	
	Aerosols & Clouds – *need 2 years of data*	Cloud Height, upper trop. aerosols and thin cirrus	Cirrus ice content		Aerosols (AOT 10 - 30%) Cloud Height
3. Determining how localized tropospheric pollution sources contribute to regional and global pollution. 4. Determining influences on the global oxidizing capacity of the troposphere.	Tropospheric Ozone – *need 1 year of data*	Upper trop. O_3, H_2O Accuracy of 3-10%	Upper trop. O_3, H_2O Accuracy of 5-10% (MLS Primary)	Trop. O_3 accuracy of 5-10% (nadir - TES Primary) Upper trop. O_3, 3-10% accuracy	Tropospheric O_3 residual, 10% (uses HIRDLS or MLS and ozone column)
	Tropospheric Ozone Precursors Accuracy req. varies with species – *need 1 year of data*	Upper trop. HNO_3, H_2O, upper trop thin cirrus and aerosols	Upper trop. HNO_3, CO, H_2O (MLS Primary)	Tropospheric CO, H_2O (nadir - TES Primary) Upper trop. HNO_3, H_2O, CO (limb)	Column NO_2, Tropospheric Aerosols, BrO

All measurements in white are duplicated, for limb meas. HIRDLS is primary, MLS secondary, TES is tertiary, except as noted.

No back up measurement exists, major loss. Measurement can be recovered from TES spectrum.

Measurement can be recovered with models. Not a major loss. For the life of 2.5 THz radiometer.

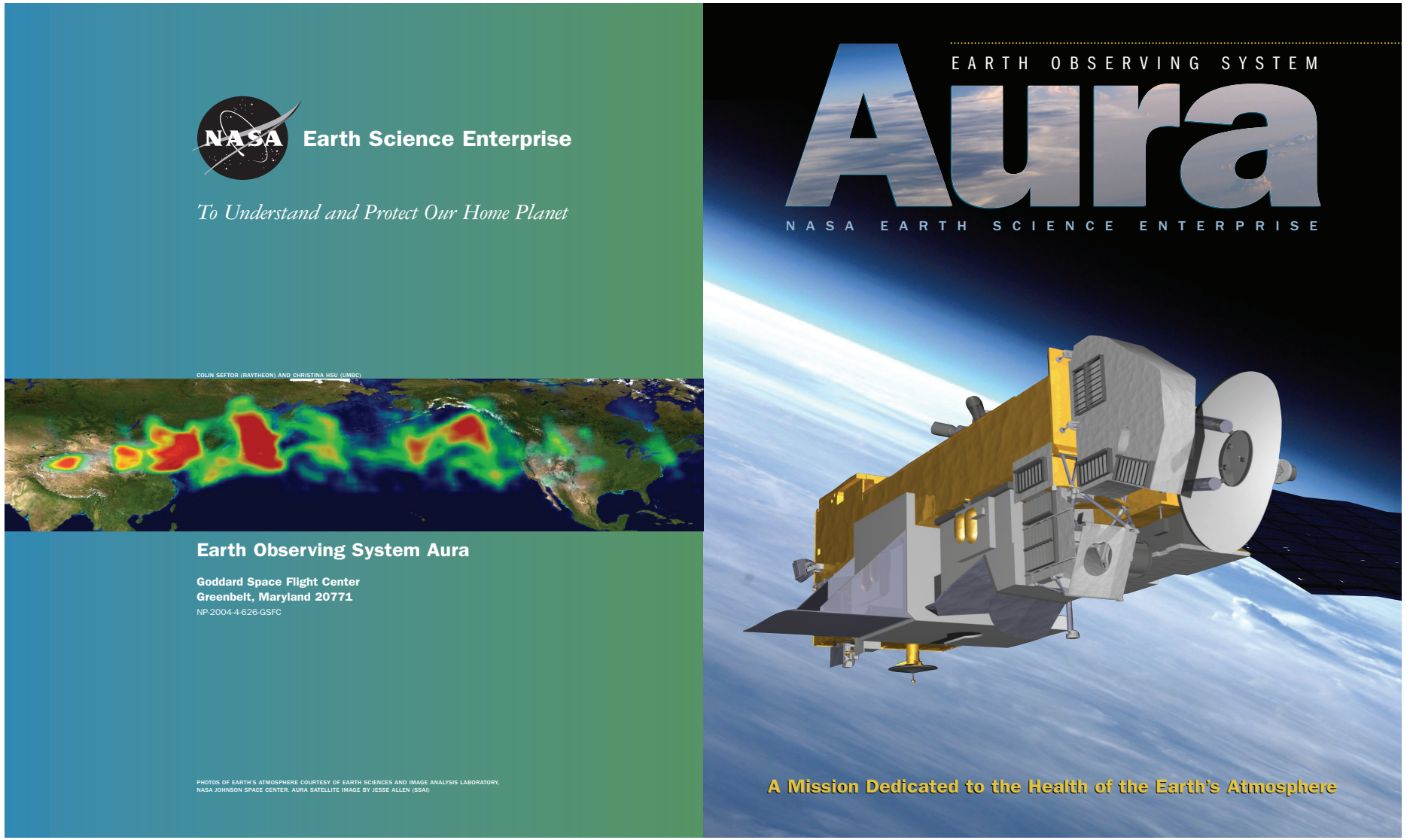
Linking the Instruments



Joe Waters originated this bar chart type presentation

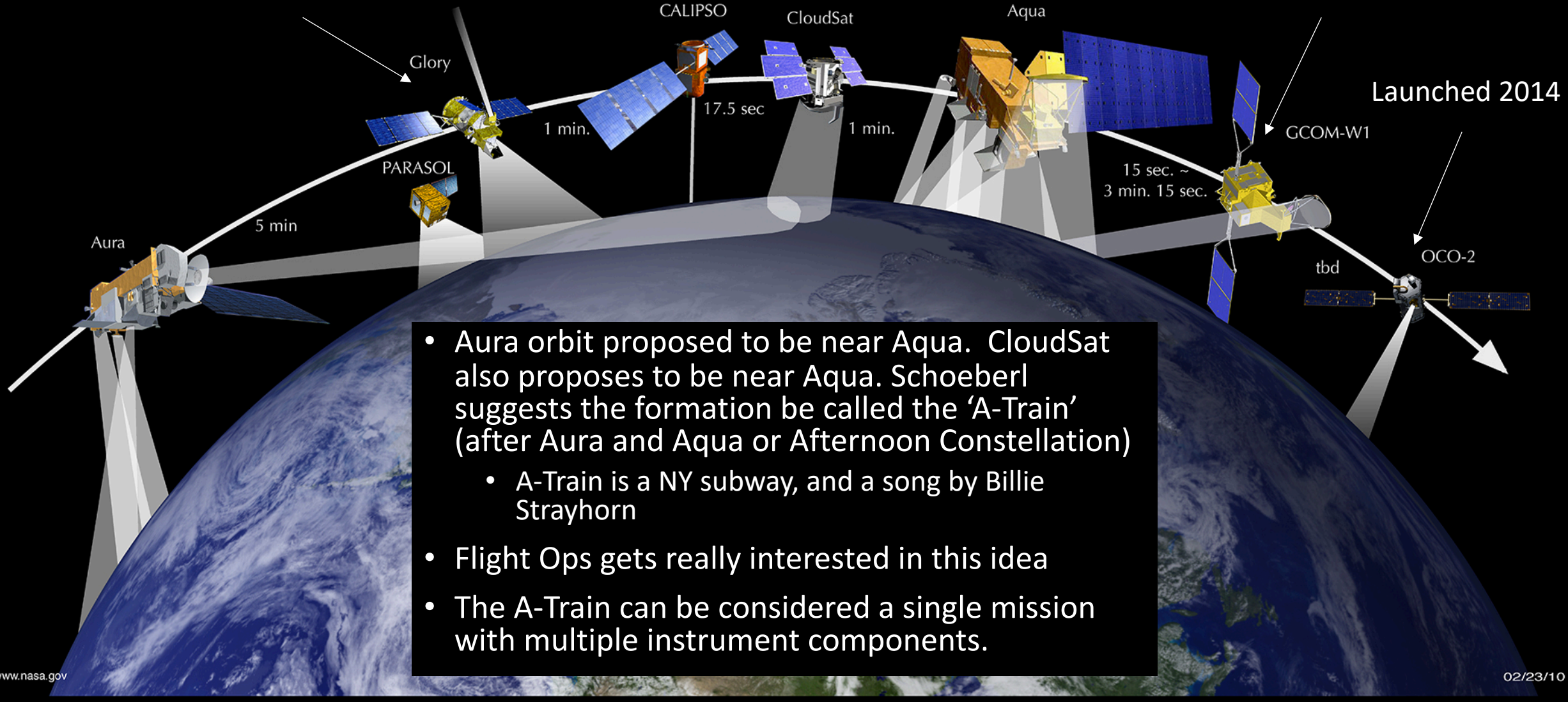
Aura Project Mission Brochure – 2004

(authored by the Project Science Office)



National Aeronautics and Space Administration

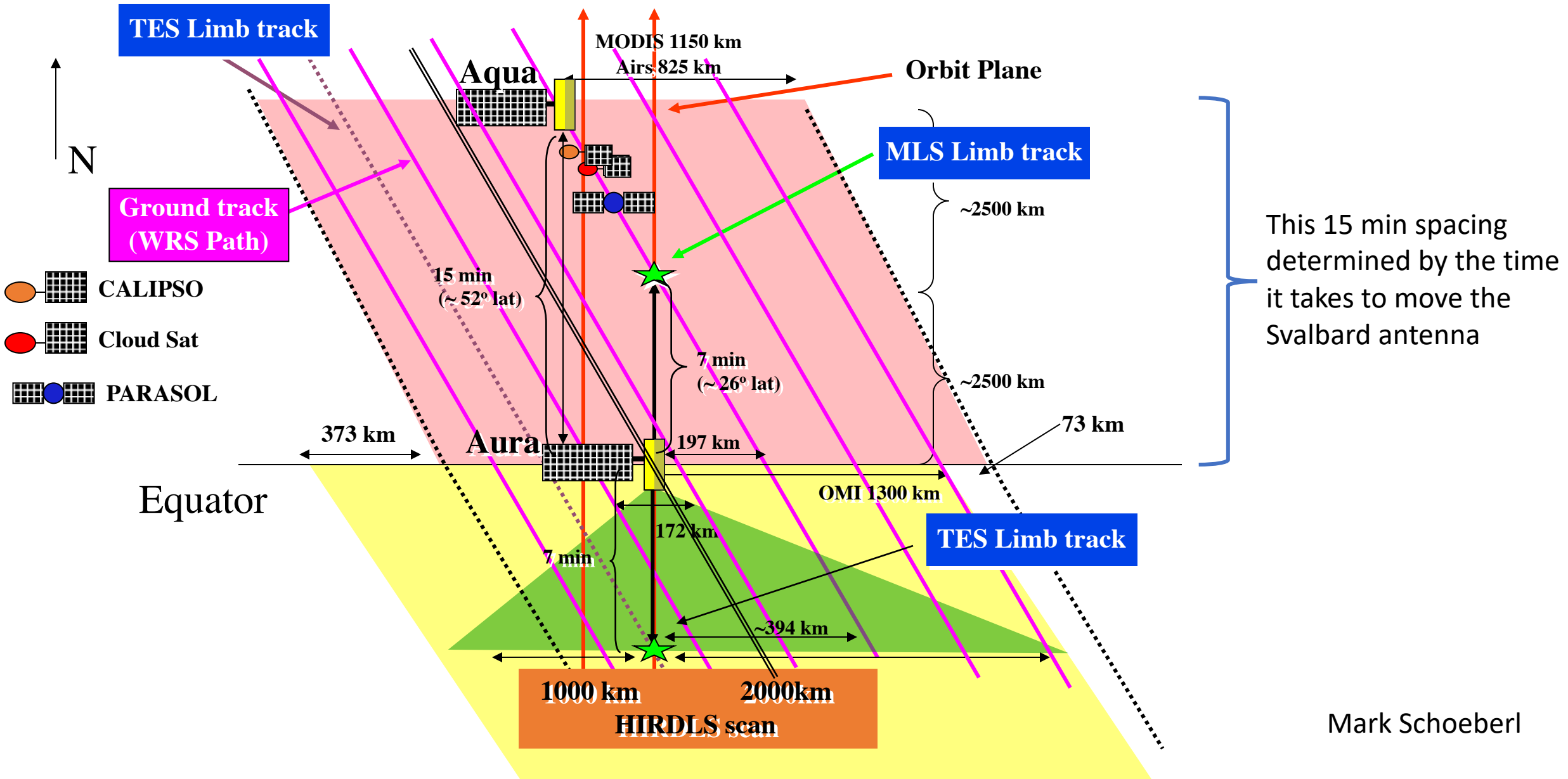
The Afternoon Constellation "A-Train"



- Aura orbit proposed to be near Aqua. CloudSat also proposes to be near Aqua. Schoeberl suggests the formation be called the 'A-Train' (after Aura and Aqua or Afternoon Constellation)
  - A-Train is a NY subway, and a song by Billie Strayhorn
- Flight Ops gets really interested in this idea
- The A-Train can be considered a single mission with multiple instrument components.

Formation flying with Aqua plan before launch

Aura and Aqua have different WRS paths.



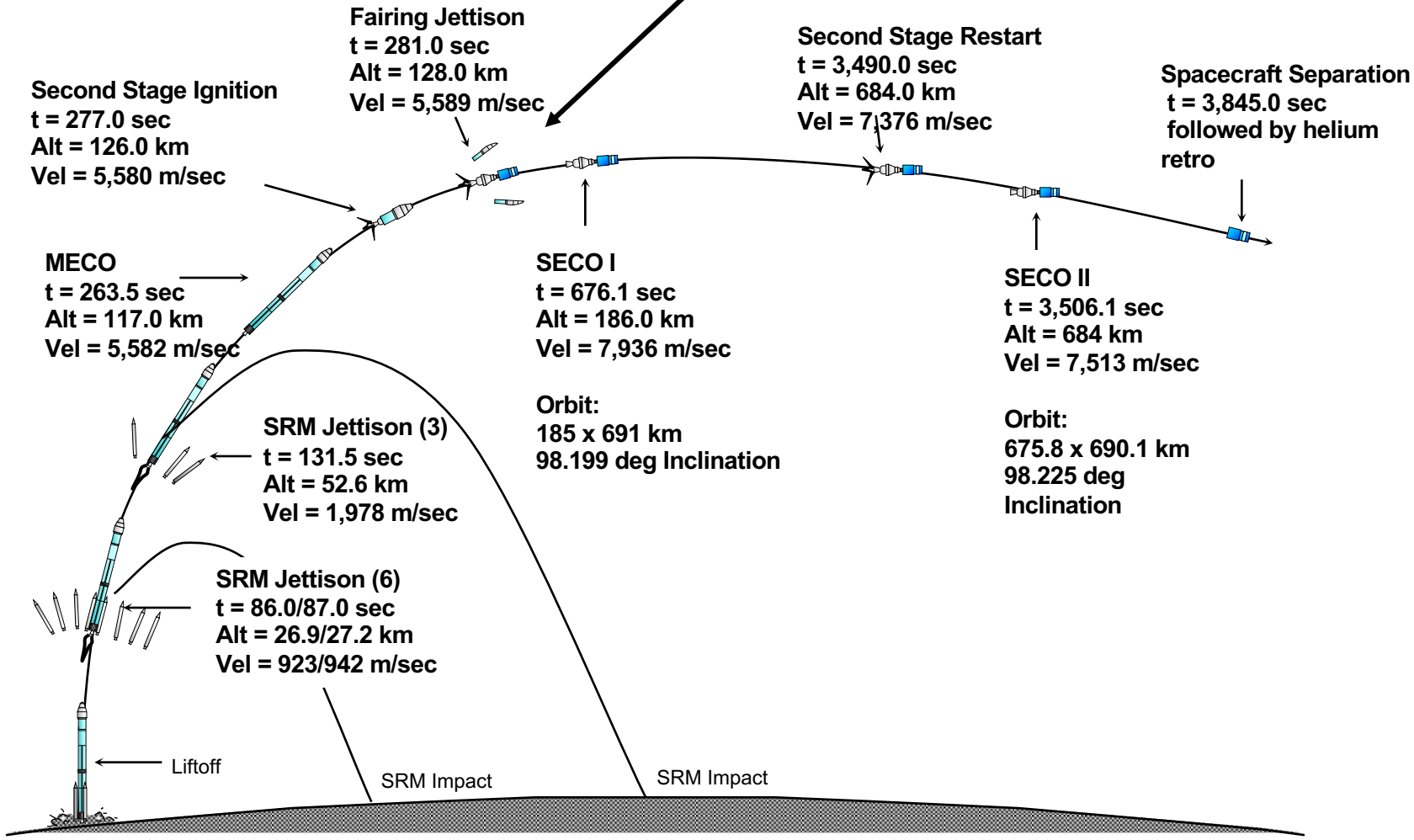
This 15 min spacing determined by the time it takes to move the Svalbard antenna

Mark Schoeberl

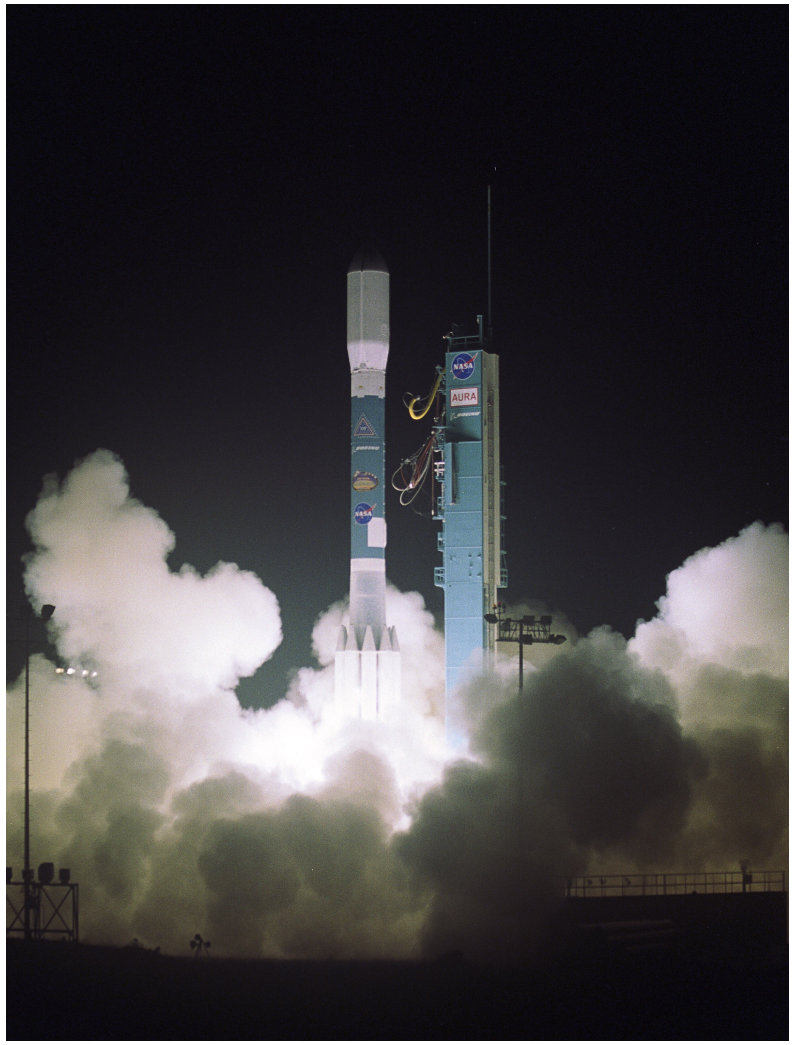
EOS Aura Satellite

Aura Flight Profile

HIRDLS Kapton flutters in front of scan mirror as a result of decompression



Aura Launch
2004 July 15



(after multiple scrubs)

Aura Lessons Learned

- More communication – fewer reviews
  - Some reviews are necessary, but too many reviews are often counter productive
  - Better to have more informal group meetings and informal communication
- Scientists (PIs and PS's) and engineers need to work together during all phases of the instrument development especially when cost constraints require trades that might degrade some of the instrument capabilities.
- Never skip the engineering model step
- Other programs will always try and take your funding until it costs more to kill your mission than it will cost to finish it.
- Instrument PIs need to be partners in any validation plans
- The quicker you can get *some* science results out after launch the better – it shuts up the critics.
- Excellent documentation increases use of the data (e.g. MLS)

Final Acknowledgements

- This mission was a lot of work by a lot of people – I can't name them all, but I would like to especially thank a few.
  - Aura Project Science Office - Anne Douglass, Ernie Hilsenrath, Joanna Joiner, PK Bhartia who (with Ernie) worked the OMI magic
  - PI's Joe Waters, Nathaniel Livesey (MLS), Pieternel Levelt (OMI), Reinhard Beer & successors (TES), John Gille & John Barnett (HIRDLS)
  - The working groups … under multiple leaderships
  - NASA HQ – Ghassem Asrar, Joe McNeal, Phil DeCola, Mike Kurylo
  - Finally, our immediate ancestor… UARS – without UARS's success, Aura would not have happened. And before UARS… Nimbus 7 TOMS and LIMS.